EMERGING TRENDS IN THE GLOBALIZATION OF KNOWLEDGE: THE ROLE OF THE TECHNICAL REPORT IN AEROSPACE RESEARCH AND DEVELOPMENT

Thomas E. Pinelli, Ph.D.
NASA Langley Research Center
Mail Stop 400,
Hampton, VA 23681-0001
U.S.A.

and

Vicki L. Golich, Ph.D.
Department of Political Science
California State University
San Marcos, CA 92096-0001
U.S.A.

Paper presented at the Third International Conference on Grey Literature
Jean Monnet Building, Luxembourg
13-14 November 1997

EMERGING TRENDS IN THE GLOBALIZATION OF KNOWLEDGE: THE ROLE OF THE TECHNICAL REPORT IN AEROSPACE RESEARCH AND DEVELOPMENT

Thomas E. Pinelli and Vicki L. Golich

SUMMARY

Economists, management theorists, business strategists, and governments alike recognize knowledge as *the* single most important resource in today's global economy. Because of its relationship to technological progress and economic growth, many governments have taken a keen interest in knowledge, specifically its production, transfer, and use. This paper focuses on the technical report as a product for disseminating the results of aerospace research and development (R&D) and its use and importance to aerospace engineers and scientists. The emergence of knowledge as an intellectual asset, its relationship to innovation, and its importance in a global economy provides the context for the paper. The relationships between government and knowledge and between government and innovation are used to placed knowledge within the context of publicly-funded R&D. Data, including the reader preferences of NASA technical reports, are derived from the *NASA/DoD Aerospace Knowledge Diffusion Research Project*, a ten-year study of knowledge diffusion in the U.S. aerospace industry.

INTRODUCTION

Knowledge is a building block, an essential ingredient of technological innovation. Innovation is necessary for creating *new* processes, products, systems, or services. Advances in knowledge are widely regarded as major sources of *improvements* in existing processes, products, systems, or services. The rate at which knowledge is created, diffused (i.e., spread, distributed, transmitted), and absorbed or utilized influences the rate of technological innovation and progress (Mansfield, 1984, 1981). Advancements in technological innovation require investments in capital, labor, and knowledge to produce tangible results that are sold in today's global markets. A firm that produces processes, products, or systems or delivers services is deemed competitive if it can provide goods and services of superior quality or lower costs than its competitors. Countries with many competitive firms typically have high rates of economic growth and standards of living, hence the interest on the part of governments in technological innovation and progress.

For many economists, knowledge is the catalyst that helps allocate resources and makes a free market function. Economists now view knowledge as an engine of change and embrace it in their theoretical constructs. Many economists see knowledge living up to Daniel Bell's (1973) prediction: Knowledge will replace capital and energy as the primary wealth-creating assets, just as capital and energy replaced labor and land (Haeckel and Nolan, 1993). In an economic sense, knowledge differs from other so-called commodities or resources: (a) it is not depleted with use, it is sharable, and traditionally, it has had no intrinsic value; (b) it is difficult

to distinguish between knowledge and the medium in which it is contained; (c) except for knowledge-based products and services designed to be sold, most knowledge lacks markets in which value can be determined by supply and demand; (d) unlike other so-called commodities or resources, the overwhelming importance of knowledge is as a public good (Noll, 1993); and (e) numerous individuals located at various points across the globe can possess the same knowledge, unlike other commodities or resources (Brinberg, Pinelli, and Barclay, 1995; Brinberg and Pinelli, 1993). The past 20 years have witnessed the propensity of knowledge to cross national boundaries, a phenomenon that observers have labeled the *globalization of knowledge*. The boundary–spanning propensity of knowledge is due mainly to improvements in communications (e.g., the Internet), transportation (e.g., international air travel), and the fact that developed and developing countries are spending more on creating and acquiring knowledge. The globalization of knowledge requires that firms and organizations involved in innovation construct and employ strategies for exploiting extramural research and development strategies and systems for acquiring knowledge produced around the world to compete in today's global economy (Ives and Jarvenpae, 1993).

KNOWLEDGE

Knowledge has replaced financial capital as the main producer of wealth. A new "information capitalism" now dominates the world economy; industries that have moved into the center of the economy in the last 40 years have as their business the production and distribution of knowledge and information (Drucker, 1993a, 1993b; Machlup, 1962). Knowledge *qua* capital represents a new and vital factor that must be added to the three factors of production—land, labor, and financial capital—traditionally studied by economists (Zhang, 1993). However, knowledge *qua* capital, or production asset, defies easy definition; therefore, existing economic theories cannot be applied to explain its behavior (Drucker, 1994). Schmookler (1966) points out that knowledge may be valued for its own sake, as a "public good," or for its application, through which it becomes a "private" or "capital good." Theorists posit a positive relationship between knowledge accumulation and economic growth (Hayek, 1945). To develop a theory of the economics of knowledge, Romer (1990), Schwartz (1992), Scott (1989), and others have begun to investigate the economic behavior of knowledge and its role in innovation.

The international business community has come to view knowledge, particularly specialized knowledge, as an essential ingredient for competitive success (Blackler, 1993). Management theorists expect improvements in knowledge-based work to contribute significantly to industrial growth and gains in productivity in the U.S. and abroad (Davenport, Jarvenpaa, and Beers, 1996). Effectively managing the creation, transfer, and use of knowledge resources is now regarded as critical for the survival and success of organizations and societies alike (Hedlund and Nonaka, 1993). Firms in such diverse industries as chemicals, pharmaceuticals, financial services, and telecommunications already consider the strategic management of knowledge—the "intellectual assets" of an organization (Hall, 1989, p. 53)—a key corporate activity and have implemented knowledge management programs. These programs emphasize the criticality of knowledge as a competitive asset and seek to maximize the ability of an organization to integrate and use various kinds of knowledge (Aaker, 1989; Bartmess and Cerny, 1993; Buckholtz, 1995; Conner and Prahalad, 1996; Grant and Baden-Fuller, 1995).

Knowledge Defined

Knowledge has been variously labeled, described, and defined. It can be scientific or technical, embodied or disembodied, tacit or explicit, and product or process knowledge. *Scientific knowledge* is embodied in the laws, principles, and theorems of a specific discipline (e.g., Newton's three laws of motion in physics). It is easily codified and is unlikely to be altered by language and culture. *Technical knowledge* tends to be narrowly focused or specific; it is not always predictable, and it does not necessarily spring from scientific knowledge. Technical knowledge is not the application of scientific knowledge. It may be applicable to a particular technology like the manufacture of aircraft, but it is not easily transferred or applied to another technology. It is cumulative to an individual, groups of individuals, and organizations; it is derived from learning-by-doing (Arrow, 1962a; von Hippel and Tyre, 1995; Wright, 1936) or learning-by-using, and it is not easily or accurately codified. For example, after a particular jet engine has been in use for a decade, the cost of maintenance may have declined to only 30% of the initial level as a result of learning-by-using (Rosenberg, 1982).

Learning-by-doing and learning-by-using generate a substantial amount of what Rosenberg (1982) defines as *embodied* and *disembodied* knowledge. In the first case, early experience with a new technology leads to a better understanding of the relationship between design characteristics and performance that permits subsequent improvements, which over time lead to an optimal design of an aircraft, system, or component. Optimization may be achieved by applying advancements made in other areas like materials, manufacturing, or miniaturization. *Disembodied* knowledge results in slight but often continuing changes in design and operation that result from the experience of making or operating an aircraft. Prolonged experience with an aircraft, system, or component produces knowledge that can be used to lengthen the service life of an aircraft or reduce its operating cost. Rosenberg makes the point that disembodied knowledge is critical to aircraft design and manufacture because it is only through actual operation that the true performance (i.e., characteristics and costs) and full potential of a new aircraft can be determined. Vincenti (1992, 1990) provides excellent definitions and examples of knowledge as applied to aeronautical engineering. *Inside the Black Box—Technology and Economics* (Rosenberg, 1982, Chapter 6) offers convincing examples of both learning-by-doing and learning-by-using within the context of aircraft production.

When a firm or organization innovates, that is, creates or improves a process, product, system, or service, it generally does so by using both *tacit* and *explicit* knowledge. Polanyi (1966) provides the following basic definitions for these two types of knowledge: *Tacit* knowledge is personal, context-specific, and therefore, hard to formalize and communicate; *explicit* knowledge is codified and refers to knowledge that is transmittable in formal, systematic language and includes grammatical statements, mathematical expressions, specifications, and manuals. Bateson (1973) offers the following distinctions between these two types of knowledge: Tacit knowledge tends to be experiential and subjective. It is derived from practice, created "here" and "now" in a specific context, and entails what Bateson refers to as an "analog" quality; whereas explicit knowledge tends to be rational and objective. It is derived from what is known and accepted, was created "there" and "then," and it is oriented toward context-free theory. Tacit knowledge cannot always be codified because it often contains an important dimension of "know-how." Individuals may know more than they are able to articulate. When knowledge has a high

tacit component, it is extremely difficult to transfer without personal contact, demonstration, and involvement. Indeed, in the absence of close human contact, the diffusion of knowledge is sometimes impossible (Teece, 1981). Von Hippel (1994) argues that tacit, unlike other forms of knowledge, is often costly, difficult, and sometimes impossible to acquire, transfer, and use owing to the attributes of tacit knowledge itself. For an explanation of tacit and explicit knowledge within the context of *technical knowledge*, see Alic, Branscomb, Brooks, Carter, and Epstein (1992). Nonaka and Takeuchi (1995, Chapter 2) have proposed a theory of knowledge creation relative to the dynamics of technological innovation that contains four modes of knowledge conversion: tacit to tacit (socialization), tacit to explicit (externalization), explicit to explicit (combination), and explicit to tacit (internalization).

Knowledge as Intellectual Capital

Knowledge is an integral factor in innovation, technological change, and the economy (Nelson, 1996; Drucker, 1985). Edvinsson and Malone (1997, p. 3), referencing Wriston (1992), state that "the new source of wealth is not material, it is information, knowledge applied to work to create value." Wright (1994) notes that knowledge and knowledge-based resources are both enabling and constraining factors in the development of innovation and competitive advantage. Whereas its importance may not be fully understood in terms of economic theory, the belief that knowledge is playing an increasingly important role in the world's economy is now accepted as fact (Micklethwait and Woolridge, 1996). It is now widely accepted that a firm's competitive advantage flows from its unique knowledge (Nonaka, 1991). Competitive advantage is often determined more by the knowledge that a firm is able to keep to itself and less by knowledge that is readily diffused, imitated, exhausted, or appropriated (Kogut and Zander, 1992; Spender, 1993). Persistent, sustained competitive advantage cannot reside within the latter.

Knowledge as a concept is open to different interpretations (Popper, 1972). It is different from data and information (Hedlund and Nonaka, 1993). Although not always clear-cut, the distinction among the three in production processes is very important (Bohn, 1994). *Data* are what come directly from sensors, reporting on the measured level of some variable. *Information* is "data" that have been organized or given structure, that is, placed in context and thus endowed with meaning (Dretske, 1981; Glazer, 1991). Information tells the current or past status of some part of the production system. *Knowledge* goes further; it allows the making of predictions, causal associations, or prescriptive decisions about what to do (Bohn, 1994). Knowledge usually manifests itself as a product or service. Firms create products using both internal and external knowledge.

At a fundamental level, knowledge is created by individuals. The organization or firm creates a context and provides the environment for individuals to create knowledge (Cleveland, 1985; Lave and Wenger, 1991). Organizational knowledge creation, therefore, should be understood in terms of a process that "organizationally" amplifies and crystallizes the knowledge created by individuals (Nonaka, 1991). In its simplest form, knowledge has been defined as "knowing things" about something. Through the centuries, society has tended to recognize and reward individuals and groups of individuals (e.g., legal and medical professions) who know things (Sakaiya, 1991). Knowledge as power, knowledge residing within the firm, knowledge gained from learning-by-doing and learning-by-using, knowledge creation and utilization, and knowledge communities are well established concepts.

The concept of knowledge as intellectual assets or intellectual capital, although not new, has recently garnered significant attention within the context of knowledge-intensive or knowledge-based organizations, innovation, and knowledge management (Stewart, 1997). Intellectual assets have been categorized by Hall (1989) as intellectual property (i.e., assets with property rights, like patents, trademarks, and copyrights) and knowledge assets (i.e., reputation, goodwill, personal and organizational networks, databases, and the knowledge and experience of employees). Brooking (1997) has identified four categories of intellectual capital—market assets, intellectual property assets, human-centered assets, and infrastructure assets.

Market assets are derived from a company's relationship with its market and customers. For example, market assets for the aeronautics portion of the National Aeronautics and Space Administration (NASA) include customers (both civilian and military), reputation (and integrity) in the marketplace, repeat business (especially when customers have alternative choices), and product line(s) (knowledge created by NASA and the problem-solving capability of the organization).

Intellectual property assets include know-how, trade secrets, copyrights, patents, and trade and service marks. In the case of such public entities as the NASA aeronautics program, intellectual assets have three dimensions. *First* is the collective know-how, skill, and experience of the workforce. In NASA aeronautics, know-how includes what the enterprise as a whole knows about aeronautics, the related disciplines, or a particular aspect of aeronautics. A *second* dimension concerns the protection of intellectual property. Working with both commercial and military aeronautics, NASA is required to protect intellectual property that is propriety to a company like Boeing or Lockheed Martin or that is classified for reasons of national security. The *third* dimension concerns the NASA aeronautical knowledge base, including the diffusion of the knowledge created through public funding, in particular, those research results that can provide the U.S. aeronautics enterprise with an advantage over competitors.

Human-centered assets are the collective expertise, creative and problem-solving capability, leadership, and entrepreneurial and managerial skills embodied in the employees of the organization. Collectively, according to Brooking (1997), they constitute a knowledge-based workforce whose expertise resides within their heads. Human-centered assets differ from market, intellectual, and infrastructure assets in that they cannot be owned by the company. It is expensive to hire, sustain, and train employees. Consequently, organizations seeking to maximize their return on investment (ROI) must (a) know what skills, knowledge, and expertise each employee possesses; (b) provide an environment conducive to learning and collaboration; (c) encourage professional development; and (d) know how and why each employee is valuable to the organization. Human-centered assets, past and present, combine to give NASA its aeronautical know-how. *Infrastructure assets* include the facilities, elements, and components of the organization. They are the skeleton and glue of an organization (Brooking, 1997). The condition and operation of these assets have a direct bearing on the collective efficiency and productivity of the human-centered assets. Common infrastructure assets include buildings, roads, and utilities. The infrastructure assets within NASA aeronautics include, for example, the many unique wind tunnels (e.g., Ice-Research Tunnel), computational facilities (e.g., Numeric Aerodynamic Simulator), and research aircraft (e.g., F-15-XL). In a knowledge-based organiza-

tion, information technology (i.e., hardware, software, and networks) is considered an important infrastructure asset. The relative age, compatibility, and interoperability of information technology indirectly affects an organization's market assets, intellectual property, and human-centered assets.

GOVERNMENT, KNOWLEDGE, AND INNOVATION

Although innovation is an investment decision generally made within a firm or organization, it is also influenced, to a large extent, by public policy and the resulting laws and regulations that affect the mobilization of capital and labor (David, 1986). Government plays a major role in creating the knowledge that drives innovation through direct funding of science and technology. In addition, government decisions *potentially* have a significant impact on knowledge diffusion. Governments typically support a range of programs, from those that simply collect knowledge and make it accessible, to those that actively seek to couple knowledge with potential beneficiaries. Finally, the adoption and utilization of knowledge and innovation can be influenced through a variety of programs that provide special considerations, incentives, credits, and protections affecting investments in labor and capital.

Government and Knowledge

Governments adopt strategies and policies that they determine will enable their individual countries to be safe from external attack and to be economically viable. Innovation strategies may be categorized as follows: "mission-oriented," "diffusion-oriented," and some combination thereof (Ergas, 1987). The former is characterized by large-scale project work, centering on large firms with a heavy emphasis on areas such as defense, nuclear power, and aerospace. The latter emphasizes broader, more generalized forms of investment, notably in pre-competitive, collaborative research, standards development, and training. The former strategy emphasized the creation of knowledge over utilization of existing knowledge. In a mission-oriented strategy, knowledge diffusion is often not included or it is added as an after thought. A diffusion-oriented strategy seeks to strike a balance between knowledge creation and knowledge utilization. The diffusion of knowledge is a strategic and integral component of a diffusion-oriented strategy.

Government innovation strategy that emphasizes *knowledge creation*, in and of itself, will not ensure a nation's competitiveness in today's global economy. As Alic (1991, pp. 65-66) points out, "innovation depends heavily on existing knowledge, often more so than on new knowledge .... New knowledge, at least in the sense of research results, rarely has direct bearing on competitive outcomes." To compete effectively in a changed global economy, nations that emphasize knowledge creation as an innovation strategy might be wise to rethink such policies for the following reasons. *First*, knowledge has become a competitive resource and the currency of the global economy. *Second*, knowledge as an asset has profound implications for government policies and programs affecting innovation and competitiveness. *Third*, in a global economy, knowledge becomes an asset rather than a by-product of research and development (R&D). *Fourth*, given the globalization of knowledge, a diffusion-oriented, capability-enhancing innovation policy becomes desirable over a mission-oriented innovation policy as a strategy for government-supported innovation (Ergas, 1987). *Fifth*, the effectiveness of a diffusion-oriented,

capability-enhancing innovation policy is increased by including a system and methods for effectively and strategically managing the knowledge that results from government-funded R&D.

Government innovation strategies that emphasize *knowledge creation* reflect the dominant political-social view that (a) the route to successful innovation is through basic research, (b) the knowledge necessary for successful innovation comes from basic research, (c) technology is little more than applied science, and (d) apart from basic research, the remaining components of product and process innovation (e.g., design, development, production) are not the purview of government and, therefore, should be left to the private sector. Increasingly, the importance of the linkage between the knowledge generated by basic research and commercial innovation has come under challenge (Kash, 1992). In fact, critics have begun to question the existence of a linkage. Study results indicate that economically successful innovation is frequently the product of incremental improvements in existing technologies (Kash, 1989) and that many breakthrough innovations stem from invention or trial and error learning, rather than basic research (Constant, 1980).

Furthermore, innovation is an inherently uncertain undertaking that involves the use of human and financial resources coupled with knowledge and technology to create new or improve existing products, processes, and services. As a system, innovation interacts with government at two basic levels. The first relates to harnessing knowledge and technology for public purposes. The second arises from the reliance of innovation on social context; that is, education and training to create a skilled workforce; a legal framework for defining and enforcing intellectual property rights, laws and regulations conducive to innovation as an essential engine of growth; and a variety of public policies that support the production, transfer, and use of knowledge and technology.

Additionally, industrial R&D funds are becoming scarce. To maximize scant resources, firms have begun developing R&D partnerships—cooperative arrangements in which companies join with other companies, universities, and government laboratories—to pursue their mutually agreed-upon R&D objectives. The participation of government agencies and government laboratories in R&D partnerships and cooperative arrangements raises questions about the proper role of government in innovation. Participants in these arrangements agree to share costs, resources, and expenses. The ownership and use of R&D results are usually covered in such cooperative (written) arrangements. However, ownership, use, and protection of intellectual property as a public or private good (and capturing its revenue, in particular) have become increasingly contentious factors in many government, industry, and university arrangements.

The most highly developed, currently successful innovation is carried out by the partnerships (i.e., academia, government, and industry) that have evolved in aerospace, agriculture, and medicine (Kash, 1989). These partnerships exist at the levels of complexes and networks. A complex refers to all of the organizations in a particular sector (e.g., aerospace) that are either involved in or contribute to the process of innovation in that sector. Each complex is characterized by multiple and ever-changing networks involved in the innovation of the products, processes, and systems specific to each sector. Networks are composed of the collective expertise located in organizations that innovate and create the products, processes, and systems used in the sector.

Lastly, individuals, firms, and governments alike have begun to recognize the importance of knowledge and technology to innovation (Drucker, 1985), for the wise use of knowledge and technology has a direct bearing on a firm's and nation's competitive advantage. Increased spending on science and technology by all industrialized nations, coupled with global transportation and communications capabilities, has decreased the lead time that any firm may have with respect to acquiring and applying knowledge and technology. Consequently, many firms and nations have come to view both explicit and tacit knowledge (i.e., knowledge embedded in processes and products; Badaracco, 1991) and technology as strategic intellectual assets that can be managed to gain or improve competitive advantage in a global economy (Alvesson, 1995). Firms and nations now also accept that funding knowledge and technology creation and utilization, although costly, are legitimate expenditures and, therefore, have begun to implement strategies, policies, and tools for managing intellectual assets. The understanding of and commitment to knowledge as a source of competitive advantage are quite different among governments.

Government and Innovation

The process of innovation, applied within a capitalist system, relies primarily on market forces and the use of human, technical, and financial resources to create new and improve existing processes, products, systems, and services. However, investments in creating and improving knowledge differ from investments in physical capital in that the results, once produced, become, in principle, free goods unless steps are taken to prevent that from happening (Matthews, 1973). This creates a basic public policy dilemma. If exclusive rights are granted to those investing in creating and improving knowledge, from a social perspective, the use of that knowledge becomes wastefully restricted. If no such rights are granted, no incentive exists to invest in creating and improving knowledge. Without knowledge, there is no innovation. Innovation begets technical progress and economic growth, and economic growth fosters technological innovation, creates jobs, and generally raises the standard of living. Therefore, from a public policy perspective, government funding of science and technology provides considerable social benefits.

Government interacts with the process of innovation at three essential levels (Ergas, 1987). *First*, the government promotes the generation of these critical public goods—technological innovation—through the production and purchase of goods and services. Though this type of government involvement has frequently been limited to goods and services integral to providing for the nation's defense and military security; governments have also intervened to encourage knowledge creation and technological innovation that could benefit the commercial sector. For example, NASA's precursor—the National Advisory Committee for Aeronautics (NACA)—was charged with the creation and development of aeronautical knowledge and technology that would benefit *both* military and commercial aviation. (Much, if not most of this knowledge and technology, was documented in technical reports.) More frequently, many governments around the world, including in some cases the United States, have targeted commercially relevant knowledge and technological innovation as a critical component of their overall economic security and competitiveness.

Second, the government facilitates the creation of knowledge and the development of technological innovation and the creation of new and improved processes, products, systems, and services by funding science and technology. Funding occurs at many levels—through entities

such as the National Science Foundation (NSF), through Congressional legislation targeting specific knowledge and technology needs, through grants to universities, and through partial funding to a variety of research consortia such as the IC^2 (Innovation, Creativity, and Capital) Institute at the University of Texas at Austin or the Agile Manufacturing Research Institutes (AMRI) at Rensselaer, University of Texas at Arlington, and the University of Illinois.

Third, the government supports the education and training of engineers and scientists, provides a legal system for defining and enforcing property rights and contracts, and maintains a uniform system for conducting commerce (i.e., weights and measures, currency values, and interest and exchange rates). Such activity helps to create the "human capital" imbued with the requisite types of knowledge and skills that enables them to create private knowledge and technology, to innovate, and to create private goods incentives (e.g., new and improved processes, products, systems, and services) through patents and copyrights that will protect and generate economic compensation for innovation, and to create a stable and predictable market environment that is imperative for wealth-creating trade to occur.

Although every national government employs a variety of these "intervention instruments" to promote knowledge creation and innovation, tradition and political culture have combined to forge different styles—some more "activist" than others—among nations. For example, "mission-oriented" knowledge and technology strategies are characteristic of the U.S., the U.K., and France. Germany has adopted a "diffusion-oriented" strategy. Japan has adopted a unique hybrid approach to knowledge creation, technological development, and innovation. Moreover, European countries—both individually and collectively—and Japan are more likely to intervene directly and proactively (in knowledge creation, technological development, and innovation) using transparent public policy tools to achieve specific goals, whereas the United States tends to intervene less directly, only occasionally proactively, and often using less opaque public policy tools.

THE NASA TECHNICAL REPORT

The technical report is a primary means by which the results of R&D are documented and disseminated throughout the U.S. aerospace industry. However, little is known about this information product in terms of its actual use, importance, and value in diffusing the results of R&D. NASA maintains scientific and technical information (STI) system for acquiring, processing, announcing, publishing, and transferring the results of government-performed and government-sponsored research. Within that system, the NASA technical report is considered a primary mechanism for transferring the results of this research to the U.S. aerospace community.

Use and Importance of NASA Technical Reports

Within the context of other forms of literature, about 78% of the participants used NASA technical reports. Participants were asked to indicate the number of times they had used NASA technical reports during a six-month period in the performance of their professional duties. On the average, NASA technical reports were used about 11.5 times. Participants were asked to indicate, from a list of choices, their reasons for not using NASA technical reports. Reasons for nonuse, in decreasing order of frequency, include (a) not relevant to my research, (b) not used

in my discipline, and (c) not available or accessible. Participants who used NASA technical reports were asked how they usually use them. The responses indicate that NASA technical reports are used for three general purposes: education/professional development, research, and management. About 64% indicate that they use NASA technical reports for research purposes and about 16% indicate that they use NASA technical reports for education/professional development. About 13% indicate they use NASA technical reports for management purposes. NASA technical reports are important to U.S. aerospace engineers and scientists in the performance of their professional duties. Using a 5-point scale, participants rated the importance of NASA technical reports 3.51.

Factors Affecting Use of NASA Technical Reports

The relevant literature overwhelmingly favors accessibility as the single most important determinant of use. It is, therefore, hypothesized that the influence of accessibility on use would also apply to NASA technical reports. Participants who use them were asked to indicate the extent to which seven factors influenced the use of NASA technical reports. Overall, relevance exerts the greatest influence on the use of NASA technical reports. Technical quality or reliability, followed by accessibility exerts the greatest influence on the use of NASA technical reports.

Information-Seeking Behavior and NASA Technical Reports

Participants were asked if they had used NASA technical reports to complete their most recent technical project, task, or problem. Next, these same participants who used them were asked how they found out about NASA technical reports. Approximately 65% of the participants indicated that they had used NASA technical reports to complete their most recent technical project, task, or problem. In completing their most recent technical project, task, or problem, participants used their personal collection of information first, followed by discussions with a co-worker or key individual in their organization. Next, they searched the library or a database and, asked a librarian.

RESULTS OF THE READER PREFERENCE SURVEY CONCERNING NASA LANGLEY RESEARCH CENTER TECHNICAL REPORTS

To learn more about the preferences of U.S. aerospace engineers and scientists concerning the format of NASA Langley Research Center-authored technical reports, we surveyed 133 report producers (i.e., authors) and 137 report users in 1993 and 1994 using mail (self-reported) questionnaires. The response rates for report producers (i.e., authors) was 68% and for users was 62%. Questions covered such topics as (a) the order in which report components are read, (b) components used to determine if a report would be read, (c) those components that could be deleted, (d) the placement of such components as the symbols list, (e) the desirability of a table of contents, (f) the format of reference citations, (g) column layout and right margin treatment, and (h) and person and voice.

Order in Which Users Read or Review Report Components

Survey respondents were asked to use the technical report provided and to number a list yof report components to indicate the chronological sequence in which these components are gen-

erally read. The question as it appeared in the questionnaire is shown below. The format for a typical NASA LaRC technical report appears below. Please number IN ORDER, the components you generally read/review. (For example, if you read the "ABSTRACT" first, number it with a "1." Do not number those components you skip.

a.____Title Page	i.____Description of Research Procedure
b.____Foreword	j.____Results and Discussion
c.____Preface	k.____Conclusions
d.____Contents	l.____Appendixes
e.____Summary	m.____References
f.____Introduction	n.____Tables
g.____Symbols List	o.____Figures
h.____Glossary of Terms	p.____Abstract

Table 1 shows, for each component, the percentage of survey respondents who indicated they read that component at some stage in the use sequence. The report components are listed in descending frequency of use. For the *internal* respondents, the components read by the highest percentage of readers were the results and discussion and the conclusions. Other components read by more than 80% of the internal respondents were the introduction, description of the research procedure, and the title page. For the *external* respondents, the components read by the highest percentage of readers were the conclusions and the summary. Other components read by more than 80% of the external respondents were the title page and the abstract. Components read by 80% of both groups were the conclusions (94.7%), results and discussion (87.6%), introduction (83.1%), title page (82.5%), and the summary (82.2%). Conversely, certain components were read by very few respondents in either survey group. The foreword and preface had very low usage rates: *internal* respondents 15.9%/15.2 and *external* respondents 38.9%/32.9%. (With the exception of NASA Special Publications, NASA LaRC technical reports generally do not include a foreword or preface.) Other components read by less than half of both groups include the glossary of terms (29.1%) and the symbols list (37.5%).

To clarify sequence of use of report components, a weighted average ranking was calculated and is presented in Table 2. Weighted average rankings were used to determine the order of use of the 16 report components. The weighted average rankings were obtained by assigning weights based on specific order of use. A weight of 16 was assigned for the component read first, 15 for components read second, decreasing sequentially to 1 for components read sixteenth. The weighted was calculated by the formula

$$\frac{\sum n_i w_i}{n_t}$$

where ni was the number of users reading a component in the "ith" position, w_i was the weight assigned for the "ith" position, and n_t was the total number of users who read that component in any position.

When both groups were combined, the resulting mean sequence for the first six components read was title page, abstract, summary, introduction, conclusions, and table of contents. Examined separately, the internal and external groups showed the exact overall patterns in sequential positions. Although the abstract appears on the last page of a NASA report, this component was read by about 74% of the internal and 82% of the external respondents. Moreover, the abstract was the second report component read by both report producers and users.

Table 1. Percentage of Survey Respondents Who Read Various Langley-Authored Technical Report Components

Internal Survey (n = 137)		External Survey (n = 133)		Combined Surveys (n = 270)	
Component	Percentage who read	Component	Percentage who read	Component	Percentage who read
Title page	81.6	Title page	83.3	Title page	82.5
Abstract	74.3	Abstract	82.0	Abstract	78.2
Introduction	90.3	Introduction	75.8	Introduction	83.1
Table of contents	43.6	Table of contents	59.9	Table of contents	51.8
Conclusions	94.7	Conclusions	94.6	Conclusions	94.7
Foreword	15.9	Foreword	38.9	Foreword	27.4
Results and discussion	95.5	Results and discussion	79.6	Results and discussion	87.6
Description of research procedure	84.5	Description of research procedure	59.3	Description of research procedure	71.9
Preface	15.2	Preface	32.9	Preface	24.1
Figures	79.4	Figures	62.3	Figures	70.9
Symbols list	47.3	Symbols list	27.7	Symbols list	37.5
Glossary of terms	31.9	Glossary of terms	26.2	Glossary of terms	29.1
Tables	63.3	Tables	50.2	Tables	56.8
References	63.3	References	49.5	References	56.4
Appendixes	62.6	Appendixes	39.7	Appendixes	51.2
Summary	79.4	Summary	85.0	Summary	82.2

Table 2. Weighted Average Ranking: Order in Which LaRC-Authored Technical Report Components Are Read

Internal Survey (n = 137)			External Survey (n = 133)			Combined Surveys (n = 270)		
Component	n	Weighted avg. rank*	Component	n	Weighted avg. rank*	Component	n	Weighted avg.rank*
Title page	113	15.8	Title page	112	15.6	Title page	225	15.7
Abstract	103	14.5	Abstract	109	13.9	Summary	223	14.2
Summary	110	13.5	Introduction	102	12.2	Abstract	212	13.5
Introduction	125	12.4	Table of contents	77	10.8	Introduction	227	12.3
Conclusions	131	11.5	Conclusions	127	11.3	Conclusions	258	11.4
Table of contents	61	11.4	Foreword	53	10.5	Table of contents	138	11.1
Description of			Results and discussion	107	10.6	Foreword	239	10.5
research procedure	117	10.7	Description of			Description of		
Results and discussion	132	10.4	research procedure	80	10.0	research procedure	197	10.4
Figures	110	10.0	Preface	45	9.4	Figures	194	9.8
Symbols list	66	8.4	Figures	84	9.5	Results and discussion	76	9.7
Tables	88	7.9	Symbols list	38	6.5	Preface	67	8.5
References	88	7.8	Glossary of terms	36	5.6	Tables	156	8.0
Foreword	23	7.8	Tables	68	8.2	Symbols list	104	7.6
Appendixes	45	6.6	References	67	6.6	Glossary of terms	155	7.3
Glossary of terms	88	6.5	Appendixes	54	6.0	References	141	6.7
Preface	22	6.5	Summary	113	13.5	Appendixes	81	6.1

*Highest number indicates component was read first; lowest number indicates component was read last.

Components Reviewed or Read to Determine Whether to Read the Full Report

The respondents were asked to indicate which report components (up to five) were used to decide whether to read the report. Respondents were asked to indicate the order in which these components were read. Table 3 lists the five components most frequently used by survey respondents in reviewing reports for possible reading and the percentage use by each group. Respondents from both groups identified the abstract (71.6%/67.7%) as the component most often reviewed to determine if a report would actually be read. The summary (65.7%) was the component utilized second (most often) by the respondents to the internal respondents as a screening tool. The conclusions (57.9%) was the component utilized second (most often) by the respondents to the external respondents as a screening tool. *Internal* respondents indicated the summary, title page, conclusions, and introduction (listed decreasing frequency of use) as the components most often reviewed to determine if a report would actually be read. *External* respondents indicated the conclusions, title page, summary, and introduction (listed decreasing frequency of use) as the components most often reviewed to determine if a report would actually be read.

Table 3. Components Most Commonly Used to Review/Read LaRC-Authored Technical Reports

	Percentage of respondents indicating use of a report component	
Component	Internal Survey n = 137	External Survey n = 133
Abstract	71.6	67.7
Summary	65.7	47.7
Title Page	57.7	57.2
Conclusions	54.9	57.9
Introduction	36.7	34.0

Table 4 gives a weighted average ranking for order of use of the five components most frequently reviewed in deciding whether to read a report. This table shows that the most common sequence used by combined surveys was: title page, abstract, summary, introduction, and conclusions. The use pattern for both internal and external groups was the same as that for the combined surveys (i.e., both producers and users).

Report Components Which Could Be Deleted

Survey respondents were asked to list any NASA Langley-authored report components (up to five) that could be deleted. The most dispensable components were thought to be the foreword and preface by both survey groups. About 70% and 64% of the internal respondents suggested deleting the preface and foreword, respectively. About 39% and 38% of the external respondents suggested the foreword and the preface as components that could be deleted. About 23% of the internal respondents indicated deleting the table of contents. On the other hand, only about 5% of the external respondents suggested that the table of contents could be deleted.

Table 4. Weighted Average Ranking: Order in Which Components Are Reviewed in Deciding Whether to Read a LaRC-Authored Technical Report

Internal Survey (n = 137)			External Survey (n = 133)			Combined Surveys (n = 270)		
Component	n	Weighted avg. rank*	Component	n	Weighted avg. rank*	Component	n	Weighted avg. rank*
Title page	113	15.8	Title page	112	15.6	Title page	225	15.7
Abstract	103	14.5	Abstract	109	13.9	Abstract	212	14.2
Summary	110	13.5	Summary	113	13.5	Summary	223	13.5
Introduction	125	12.4	Introduction	102	12.2	Introduction	227	12.3
Conclusions	131	11.5	Conclusions	127	11.3	Conclusions	258	11.4

*Highest number indicates component was read first; lowest number indicates component was read last.

Desirability of a Table of Contents

Survey participants were asked a question concerning the need for and or desirability of a table of contents in NASA Langley-authored technical reports. Summaries of the results from the internal and external respondents are given in Table 5.

Table 5. Opinions of Respondents Concerning the Desirability of a Table of Contents in All LaRC-Authored Technical Reports

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
Yes, all should	21.2	29	53.4	75
No, only long reports need it	78.8	108	46.6	58

About 21% of the internal respondents indicated that all NASA Langley-authored technical reports (regardless of length) should contain a table of contents; however, of the external respondents, 53.4% expressed the need for a table of contents in all NASA langley-authored technical reports. Thus, although about 79% of the internal respondents indicated that only long reports need a table of contents, about twice as many (53.4%) external (non-NASA Langley) respondents expressed the desire for this component in all NASA Langley-authored technical reports than did their internal counterparts.

Desirability of a Summary in Addition to an Abstract

Respondents were asked a question concerning the need for a summary (appearing in the front) in addition to the abstract, which appears as back matter on the Report Documentation

Page (RDP) of NASA Langley-authored technical reports. Summaries of the results obtained from the internal and external respondents are given in Table 6. Internal respondents were about evenly divided about whether the more detailed summary should be included in NASA Langley-authored technical reports in addition to the abstract. A slight majority (50.4%) favored inclusion

Table 6. Opinions of Respondents Concerning the Desirability of a Summary in Addition to an Abstract in All LaRC-Authored Technical Reports

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
Yes, include a summary, too	50.4	69	60.2	80
No, don't bother with it	49.6	68	39.8	53

of both components. Among external respondents, however, 60.2% indicated that NASA Langley-authored technical reports should have a summary in addition to an abstract.

Location of the Definition of Symbols and Glossary of Terms

Survey respondents were asked to indicate where in a NASA Langley-authored technical report the definition of symbols and glossary of terms components should appear. Summaries of the results from the internal and external respondents are given in Tables 7 and 8.

Table 7. Opinions of Respondents Concerning the Location of the Symbols List in LaRC-Authored Technical Reports

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
After Contents	10.2	14	25.6	34
After Introduction	39.4	54	10.5	14
As an Appendix	13.9	19	19.5	26
Near front of report AND where symbols appear	15.3	21	20.3	27
Near back of report AND where symbols appear	5.8	8	10.5	14
NO Symbols List needed; just define the symbol where it appears in the report	15.3	21	13.5	18

Concerning the location of the Symbols List, the response patterns from the internal and external respondents were different. The largest percentage of internal (39.4%) and external (25.6%) respondents chose the response, "after Introduction" and "after Contents." The second highest percentages of both groups (15.3%) and (20.3%) chose "near front of report AND where

symbols appear." Thus, when results from these two responses were combined, a preference (64.9% for internal respondents and 56.4% for external respondents) was evident for the Definition of Terms to be located near the front of the report as opposed to being located as back matter.

Regarding the location of the Glossary of Terms, the response patterns from the internal and external respondents were different. The largest percentage of the internal (46.7%) respondents selected "no glossary of terms needed; just define the term where it appears in the report." The largest percentage of external respondents (30.8%) chose the response, "as an Appendix." The second highest percentage (24.8%) of the internal respondents and external respondents (15%) chose "after Contents." Thus, when results from these two responses were combined, a preference (32.1% for internal respondents and 43.6% for external respondents) was evident for the glossary of terms to be located near the back of the report as opposed to being located as front matter.

Table 8. Opinions of Respondents Concerning the Location of the Glossary of Terms in LaRC-Authored Technical Reports

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
After Contents	4.4	6	15.0	20
After Introduction	7.3	10	3.8	5
As an Appendix	24.8	34	30.8	41
Near front of report AND where terms appear	9.5	13	11.3	15
Near back of report AND where terms appear	7.3	10	12.8	17
NO Glossary of Terms needed; just define the term where it appears in the report	46.7	64	26.3	35

When Appendix Material Is Read

Survey respondents were asked a question concerning when they read appendix material—before, with, or after the text. Summaries of the results from the internal and external respondents are given in Table 9. The internal and external responses were very similar. A strong majority (73% internally and about 77% externally) indicated that the appendixes were read after the text. About 25% of the internal respondents and about 23% of the external respondents stated that the appendixes were read with the text. About 2% of the internal and 0.0% of the external respondents indicated that the appendix material was read prior to reading the text.

Location and Use of Illustrative Material

Internal and external respondents were asked three questions concerning the location and use of illustrative material (such as tables, graphs, and photographs) in NASA Langley-authored

technical reports. A summary of the results from the internal and external respondents is presented in Tables 10, 11, 12, and 13.

Table 9. When Respondents Usually Read Appendix Material
in LaRC-Authored Technical Reports

Response	Internal respondents (n = 137)		External respondents (n = 133)	
	%	n	%	n
Before the text	2.2	3	0.0	0
With the text	24.8	34	23.3	31
After the text	73.0	100	76.7	102

About 47% of the internal and about 36% of the external respondents indicated that a list of figures or tables should ONLY be included in NASA Langley-authored technical reports when there is a lot of illustrative material (e.g., over 10 figures, photos, or tables). About 34% of the internal respondents and about 29% of the external respondents reported that "No List of Figures and Tables Needed" in NASA Langley-authored technical reports. About 22% of external respondents indicated that NASA Langley-authored technical reports should always contain a list of figures or tables whenever a report contains illustrative material.

Table 10. Opinions of Respondents Concerning the Need for a List of Figures or Tables
in LaRC-Authored Technical Reports

Response	Internal respondents (n = 137)		External respondents (n = 133)	
	%	n	%	n
Only when illustrative material is integrated with the text	4.4	6	6.8	9
Only when illustrative material is separate from the text; at the end of the report	5.8	8	6.0	8
Only when there is a lot of illustrative material (e.g., over 10 figures, photos or tables)	47.4	65	36.1	48
Always; whenever a report contains illustrative material	8.0	11	21.8	29
No List of Figures and Tables needed	34.3	47	29.3	39

Internal and external respondents were asked about the integration of illustrative material as opposed to group it at the end of the report (Table 11). The survey results show that about 77% of the internal and about 80% of the external respondents preferred that the illustrative material be integrated with the text as opposed to being grouped in the back matter.

Table 11. Opinions of Respondents Concerning Integration of Illustrative Material as Opposed to Grouping It At the End of NASA LaRC-Authored Technical Reports

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
Integrated with text	77.4	106	79.7	106
Separate from text; at end of report	22.6	31	20.3	27

Table 12 contains the responses to the third question concerning the placement of illustrative material. About 31% of the internal and about 50% of the external respondents indicated that integration of tables and figures did not interrupt their reading no matter how much illustrative material the report contained. The illustrative-page/text-page ratio which interrupted reading was placed at two by about 49% of the internal respondents and about 35% of the external respondents; at three by about 14% of internal and 9% of external respondents; and at four or more by about 6% of internal and 6% of external respondents.

Table 12. Opinions of Respondents Concerning the Amount of Illustrative Material That Can be Integrated with the Text of LaRC-Authored Technical Reports Without Interrupting the Reader

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
Yes, when there are two pages of illustrative material for every page of text	48.9	67	35.3	47
Yes, when there are three pages of illustrative material for every page of text	13.9	19	9.0	12
Yes, when there are four or more pages of illustrative material for every page of text	5.8	8	6.0	8
No, I always prefer to have illustrative material integrated in text	31.4	43	49.6	66

Finally, respondents were asked when they read the illustrative included in NASA Langley-authored technical reports. Summaries of the internal and external responses are presented in Table 13.

Table 13. When Respondents Usually Read Illustrative Material in LaRC-Authored Technical Reports

Response	Internal respondents (n = 137)		External respondents (n = 133)	
	%	n	%	n
Before the text	16.8	23	18.0	24
With the text	80.3	110	79.7	106
After the text	2.9	4	2.3	3

Most respondents (80.3% internally; 79.7% externally) indicated that the illustrative material was read with the text. Some respondents (16.% internally and 18% externally) indicated that the illustrative material was read before the text. Only a few respondents (4% internally and 2.3% externally) indicated that the illustrative material was read after the text.

Format of Reference Citations

Survey respondents were asked to specify their preference between three formats for reference citations in NASA Langley-authored technical reports. Summaries of the internal and external respondents' responses are presented in Table 14.

Table 14. Preferences of Respondents Concerning the Format of Reference Citations Used in LaRC-Authored Technical Reports

Response	Internal respondents (n = 137)		External respondents (n = 133)	
	%	n	%	n
Cited in text by author/year (e.g., Jones 1978) but with an alphabetic list in back of report	27.7	38	27.8	37
Cited in text by number (e.g., reference 16) with a numbered list in back of report	52.6	72	55.6	74
Cited in text by footnote (e.g., Jones[12]) with a numbered list in back of report	19.7	27	16.5	22

About 53% of the internal respondents and about 56% of the external respondents preferred references in the text to be cited by number (e.g., reference 16) with a numbered list in back of report. About 28% of the internal respondents and about 28% of the external respondents preferred references cited in text by author/year (e.g., Jones 1978) but with an alphabetic list in back of report. About 20% of the internal respondents and about 17% of the external respondents preferred references cited in text by footnote (e.g., Jones[12]) with a numbered list in back of report.

Specifications of Units for Dimensional Values

Respondents were asked to specify their preferences regarding the use of the International System (S.I.) units and U.S. Customary units for dimensional values in NASA Langley-authored technical reports. Table 15 contains the results of the survey responses concerning this question.

Table 15. Preferences of Respondents Concerning Units for Dimensional Values Specified in LaRC-Authored Technical Reports

	Internal respondents (n = 137)		External respondents (n = 133)	
Response	%	n	%	n
The International System (S.I.) units (e.g., meter, kilogram)	24.1	33	26.3	36
U.S. Customary units (e.g., foot, pound)	38.0	52	22.6	30
S.I. units with U.S. Customary units in parentheses	15.3	21	18.8	25
U.S. Customary units with S.I. units in parentheses	22.6	31	32.3	42

There was no overall agreement among either survey groups as to how dimensional values should be specified in NASA Langley-authored technical reports. Thirty-eight percent of the internal respondents selected U.S. Customary units (e.g., foot, pound) followed by the International System (S.I.) units (24.1%), and U.S. Customary units with S.I. units in parentheses (e.g., meter, kilogram) (22.6%). About 32% of the external respondents selected U.S. Customary units with S.I. units in parentheses, followed by the International System (S.I.) units (e.g., meter, kilogram) (26.3%), and U.S. Customary units (e.g., foot, pound) (22.6%).

Column Layout and Right Margin Treatment

Respondents were asked to state their preferences concerning one or two column layouts and ragged or justified right margins. Table 16 summarizes the results of survey respondents. About 41% of the internal respondents preferred two columns; justified right margin, followed by a mixed format; one and two columns intermixed as mathematical material dictates (21.2%). About 34% of the external respondents preferred one column; justified right margin followed by two columns; justified right margin (24.1%). Overall, a two column format (48.9%) was preferred by internal respondents and a one column format was preferred by external respondents (51.1%). Justified right margins were preferred over ragged right margins by about 53% of the internal respondents and about 63% of the external respondents.

Table 16. Preferences of Respondents Concerning Column Layout and Right Margin Treatment in LaRC-Authored Technical Reports

Response	Internal respondents (n = 137)		External respondents (n = 133)	
	%	n	%	n
Two columns; justified right margin	40.9	56	24.1	32
Two columns; ragged right margin	8.0	11	6.0	8
One column; justified right margin	12.4	17	33.8	45
One column; ragged right margin	17.5	24	17.3	23
Mixed format; one and two columns intermixed as mathematical material dictates	21.2	29	18.8	25

Person and Voice

Survey respondents were asked to specify their preference in regard to person and voice in NASA Langley-authored technical reports. Table 17 summarizes the results of the internal and external respondents.

Table 17. Preferences of Respondents Concerning Person and Voice for LaRC-Authored Technical Reports

Response	Internal respondents (n = 137)		External respondents (n = 133)	
	%	n	%	n
Passive voice, third person	64.2	88	47.4	63
Active voice, third person	14.6	20	17.3	23
Active voice, first person	21.2	29	35.3	47

Among both groups, the passive voice, third person option was chosen most often as the preferred writing style. Among internal respondents, about 64% selected this preference. Among external respondents, about 47% selected this preference. Considering voice alone, internal respondents preferred the passive voice (64%) over the active voice (35%). On the other hand, external respondents preferred the active voice (53%) over the passive voice (47%).

The majority of both internal (78.8%) and external (64.7%) respondents preferred that third person be used rather than first person in NASA Langley-authored technical reports. It should be noted, however, that a higher percentage of external respondents (35.3%) preferred first person than did the internal group (21.2%).

CONCLUDING REMARKS

Recognition of the importance of knowledge as an asset and a source of competitive advantage is driving organizations to find ways of optimizing and managing this resource. Under the general rubric of "knowledge management," organizations in the private and public sectors have begun exploring methods for creating and deriving value from explicit and tacit organizational knowledge resources. Although there is no single, agreed-upon approach to the practice, knowledge management; in general, encompasses a variety of strategies, methods, and technologies for leveraging the intellectual capital and know-how of organizations for competitive advantage. In brief, the practices associated with knowledge management include identifying and mapping both the tacit and explicit knowledge of organizations; importing potentially useful knowledge from the external environment; making relevant knowledge available to users in forms that best meet their knowledge requirements; winnowing and filtering out unnecessary or irrelevant information; creating new knowledge that can provide competitive advantage; sharing the best methods and practices for completing knowledge-based work; and applying strategies, techniques, and tools that support the foregoing activities.

Sources of knowledge external to an organization are often critical to the innovation process and to the commercial success of various products, including large commercial aircraft. Studies have proved this statement true for entire nations (e.g., Japan) and for entire industries (e.g., computers). At the organizational level, the results of studies suggest that most innovation results from knowledge that resides external to the organization. Ergo, the ability of organizations to exploit external knowledge is critical to technological innovation and R&D. Several factors affect an organization's capacity to absorb knowledge, assimilate it, and apply it to commercial ends. Several factors affect an organization's capacity to absorb knowledge, assimilate it, and apply it to commercial ends. For example, organizations that conduct their own (internal) R&D are better able to absorb external knowledge than are those organizations that do not. It appears that experience, at both the organizational and individual levels, with similar or related knowledge, determines in large part an organization's ability to evaluate, absorb, and utilize external knowledge.

The technical report is a primary means by which the results of federally funded R&D are made available to the U.S. aerospace community. The history of technical report literature in the U.S. coincides almost entirely with the development of aeronautics and the aviation industry. The boundaries of technical report literature are difficult to establish because of wide variations in the content, purpose, and audience being addressed. Their formats vary; they might be brief (two pages) or lengthy (500 pages). They appear as microfiche, computer printouts or vugraphs, and often they are loose leaf (with periodic changes that need to be inserted) or have a paper cover, and often contain foldouts. Their contents may include statistical data, catalogs, directions, design criteria, conference papers and proceedings, literature reviews, or bibliographies. Technical reports permit prompt dissemination of data results on a typically flexible distribution basis; they can convey the total research story, including exhaustive exposition, detailed tables, ample illustrations, and full discussion of unsuccessful approaches and their distribution can be limited or restricted. Therefore, technical report collections constitute an important part of an organization's intellectual assets. Nevertheless, the body of available knowledge is simply inadequate to determine the role that the technical report plays in the diffusion of knowledge in the U.S. aerospace industry.

REFERENCES

Aaker, D.A. (1989). "Managing Assets and Skills: The Key to a Sustainable Competitive Advantage." *California Management Review* (Winter) 21(2): 91-106.

Alic, J.A. (1991). "Policy Issues in Collaborative Research and Development." *The International Trade Journal* (Fall) 6(1): 63-88.

Alic, J.A.; L.M. Branscomb; H. Brooks; A.B. Carter; and G.L. Epstein. (1992). *Beyond Spinoff: Military and Commercial Technologies in a Changing World.* Boston, MA: Harvard Business School Press.

Alvesson, M. (1995). *Management of Knowledge-Intensive Companies.* New York, NY: Walter de Gruyter.

Arrow, K. (1962). "Economic Welfare and the Allocation of Resources For Invention." In *The Rate and Direction of Inventive Activity.* R. Nelson, ed. Princeton, NJ: Princeton University Press.

Badaracco, J.L. (1991). "Embedded Knowledge." Chapter 4 in *The Knowledge Link: How Firms Compete Through Strategic Alliances.* Boston, MA: Harvard Business School Press, 79-105.

Bartmess, A. and K. Cerny. (1993). "Building Competitive Advantage Through a Global Network of Capabilities." *California Management Review* (Winter) 35(2): 2-27.

Bateson, G. (1973). *Steps to an Ecology of Mind.* London, UK: Paladin.

Bell, D. (1973). *The Coming of Post-Industrial Society: A Venture in Social Forecasting.* New York, NY: Basic Books.

Blackler, F. (1993). "Knowledge and the Theory of Organizations: Organizations as Activity Systems and the Reframing of Management." *Journal of Management Studies* (November) 30(6): 863-884.

Bohn, R.E. (1994). "Measuring and Managing Technological Knowledge." *Sloan Management Review* (Fall) 36(1): 61-104.

Brinberg, H.R. and T.E. Pinelli. (1993). "A General Approach to Measuring the Value of Aerospace Information Products and Services". Paper presented at the 31st Aerospace Sciences Meeting and Exhibits of the American Institute of Aeronautics and Astronautics (AIAA), Bally's Grand Hotel, Reno, NV. (Available AIAA; 93A17511.)

Brinberg, H.R.; T.E. Pinelli; and R.O. Barclay. (1995). "Valuing Information in an Interactive Environment". Paper presented at the *International Congress on the Economics of Information,* May 18-20, Lyon, France, and sponsored by the French Higher National School of Information Science and Library (ENSSIB) and, within it, the Information Science Research Center (CERSI). (Available NTIS; 95N21977.)

Brooking, A. (1997). *Intellectual Capital: Core Asset for the Third Millennium Enterprise.* London, UK: International Thomson Business Press.

Buckholtz, T.J. (1995). *Information Proficiency: Your Key to the Information Age.* New York, NY: Van Nostrand Reinhold.

Cleveland, H. (1985). *The Knowledge Executive: Leadership in an Information Society.* New York, NY: Truman Talley Books.

Conner, K. and C.K. Prahalad. (1996). "A Resource-Based Theory of the Firm: Knowledge Versus Opportunism." *Organization Science* 7(5): 477-501.

Constant, E.W. II. (1980). *The Origins of the Turbojet Revolution*. Baltimore, MD: Johns Hopkins University Press.

David, P.A. (1986). "Technology Policy, Public Policy, and Industrial Competitiveness." In *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. R. Landau and N. Rosenberg, eds. Washington, DC: National Academy Press, 373-391.

Dretske, F.I. (1981). "Knowledge." Chapter 4 in *Knowledge & the Flow of Information*. Cambridge, MA: MIT Press, 85-106.

Drucker, P.F. (1994). "The Age of Social Transformation." *Atlantic Monthly* (November) 274(5): 53-80.

Drucker, P.F. (1993a). "From Capitalism to Knowledge Society." Chapter 1 in *Post-Capitalist Society*. New York, NY: Harper Business, 19-47.

Drucker, P.F. (1993b). "Knowledge: Its Economics and Its Productivity." Chapter 10 in *Post-Capitalist Society*. New York, NY: Harper Business, 181-218.

Drucker, P.F. (1985). "Source: New Knowledge." Chapter 9 in *Innovation and Entrepreneurship: Practice and Principles*. New York, NY: Harper & Row, 107-129.

Edvinsson, L. and M.S. Malone. (1997). *Intellectual Capital: Realizing Your Company's True Value by Finding its Hidden Brainpower*. New York, NY: Harper Collins Publishers.

Ergas, H. (1987). "Does Technology Policy Matter? In *Technology and Global Industry: Companies and Nations in the World Economy*. B.G. Guile and H. Brooks, eds. Washington, DC: National Academy Press, 191-245.

Glazer, R. (1991). "Marketing in an Information-Intensive Environment: Strategic Implications of Knowledge as an Asset." *Journal of Marketing* 55: 1-19.

Grant, R.M. and C. Baden-Fuller. (1995). "A Knowledge-Based Theory of Inter-Firm Collaboration." *Academy of Management Best Paper Proceedings*. New York, NY: Academy of Management Press, 17-21.

Hall, R. (1989). "The Management of Intellectual Assets: A New Corporate Perspective." *Journal of General Management* (Autumn) 15(1): 53-68.

Haeckel, S.H. and R.L. Nolan. (1993). "The Role of Technology in an Information Age: Transforming Symbols Into Action." In *The Knowledge Economy: The Nature of Information in the 21st Century*. Queenstown, MD: The Aspen Institute, Institute for Information Studies, 1-24.

Hayek, F.A. (1945). "The Use of Knowledge in Society." *American Economic Review* 35(4): 519-530.

Hedlund, G. and I. Nonaka. (1993). "Models of Knowledge Management in the West and Japan." Chapter 5 in *Implementing Strategic Processes: Change, Learning, and Co-operation*. P. Lorange; B. Chakravarthy; J. Roos; and A. Van de Ven, eds. Boston, MA: Basil Blackwell, 117-144.

Ives, B. and S.L. Jarvenpae. (1993). "Competing With Information: Empowering Knowledge Networks With Information Technology." In *The Knowledge Economy: The Nature of Information in the 21st Century*. Queenstown, MD: The Aspen Institute, Institute for Information Studies, 53-87.

Kash, D.E. (1992). "Innovation Policy." In the *Proceedings of the Second NISTEP International Conference on Science and Technology Policy Research*. S. Okamura; K. Murakami; and I. Nonaka, eds. Tokyo, Japan: Mita Press, 139-148.

Kash, D.E. (1989). *Perpetual Innovation: The New World of Competition*. New York, NY: Basic Books.

Kogut, B. and U. Zander. (1992). "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology." *Organization Science* (August) 3(3): 383-397.

Lave, J. and E. Wenger. (1991). *Situated Learning: Legitimate Peripheral Participation.* Cambridge, UK: Cambridge University Press.

Machlup, F. (1962). *The Production and Distribution of Knowledge in the United States.* Princeton, NJ: Princeton University Press.

Mansfield, E. (1984). "Economic Effects of Research and Development, the Diffusion Process, and Public Policy." Chapter 6 in *Planning For National Technology Policy.* R.A. Goodman and J. Pavon, eds. New York, NY: Praeger, 104-120.

Mansfield, E. (1981). "How Economists See R&D." *Harvard Business Review* (November-December) 59(6): 98-106.

Matthews, R.C.O. (1973). "The Contributions of Science and Technology to Economic Development." Chapter 1 in *Science and Technology in Eco-nomic Growth.* B.R. Williams, ed. New York, NY: John Wiley, 1-31.

Micklethwait, J. and A. Woolridge. (1996). *The Witch Doctors: Making Sense of the Management Gurus.* New York, NY: Random House.

Nelson, R.R. (1996). *The Source of Economic Growth.* Cambridge, MA: Harvard University Press.

Noll, R.G. (1993). "The Economics of Information: A User's Guide." In *The Knowledge Economy: The Nature of Information in the 21st Century.* Queenstown, MD: The Aspen Institute, Institute for Information Studies, 25-52.

Nonaka, I. (1991). "The Knowledge-Creating Company." *Harvard Business Review* (November/December) 69(6): 96-104.

Nonaka, I. and H. Takeuchi. (1995). *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation.* New York, NY: Oxford University Press.

Polanyi, M. (1966). *The Tacit Dimension.* Chicago, IL: University of Chicago Press.

Popper, K. (1972). *Objective Knowledge.* Oxford, UK: Oxford University Press.

Romer, P.M. (1990). "Endogenous Technological Change." *Journal of Political Economy* 98(5): S71-S102.

Rosenberg, N. (1982). *Inside the Black Box: Technology and Economics.* London, UK: Cambridge University Press.

Sakaiya, T. (1991). *The Knowledge-Value Revolution.* New York, NY: Kodanha America, Inc.

Schmookler, J. (1966). *Invention and Economic Growth.* Cambridge, MA: Harvard University Press.

Schwartz, J.T. (1992). "America's Economic-Technological Agenda for the 1990s." *Daedalus* (Winter) 121(1): 139-165.

Scott, M.F. (1989). *A New View of Economic Growth.* New York, NY: Oxford University Press.

Stewart, T.A. (1997). *Intellectual Capital: The Wealth of Organizations.* New York, NY: Doubleday/Currency.

Teece, D.J. (1981). "The Market for Know-How and the Efficient International Transfer of Technology." *The Annals of the American Academy of Political and Social Science* (November) 458: 81-96.

Vincenti, W.G. (1992). "Engineering Knowledge, Type of Design, and Level of Hierarchy: Further Thoughts About What Engineers Know...." In *Technological Development and Science in the Industrial Age*. P. Kroes and M. Bakker, eds. Dordrecht, The Netherlands: Kluwer Academic Publishers, 17-34.

Vincenti, W.G. (1990). *What Engineers Know and How They Know It: Analytical Studies From Aeronautical History*. Baltimore, MD: Johns Hopkins University Press.

von Hippel, E. (1994). "'Sticky Information' and the Locus of Problem Solving: Implications for Innovation." *Management Science* (April) 40(4): 429-439.

von Hippel, E. and M. Tyre. (1995). "How Learning by Doing is Done: Problem Identification in Novel Process Equipment." *Research Policy* 24(1): 1-12.

Wright, R.W. (1994). "The Effects of Tacitness and Tangibility on the Diffusion of Knowledge-Based Resources." Paper presented at the *Annual Meeting of the Academy of Management*. September 15-18, Dallas, Texas.

Zhang, W.B. (1993). "Government's Research Policy and Economic Growth: Capital, Knowledge, and Economic Structure." *Research Policy* (August) 22(4): 327-336.